

Serial No. 09/648,523

January 20, 2003

Page 2 of 13

1. An energy-trap thickness extensional vibration mode piezoelectric resonator, comprising:

a piezoelectric body including a plurality of piezoelectric layers and uniformly polarized in a thickness direction thereof; and

N number of internal electrodes, where N equals 3, 4 or 5, arranged in the piezoelectric body on top of each other with the piezoelectric layers disposed therebetween; wherein

the piezoelectric body vibrates in an (N-1)th higher-order mode of a thickness extensional vibration mode generated by applying electric fields of opposite polarity alternately in the direction of thickness to piezoelectric layers between internal electrodes, and when the thickness of a piezoelectric layer between adjacent internal electrodes in the direction of thickness is denoted by D and the thicknesses of a first and second piezoelectric layer outside the outermost internal electrodes in the direction of thickness are denoted by D_1 and D_2 , the following relationships are satisfied: $0.50 \leq (D_1 + D_2)/2D \leq 0.90$ at $N = 3$ and 4, and $0.50 \leq (D_1 + D_2)/2D \leq 0.80$ at $N = 5$.

5. An energy-trap thickness extensional vibration mode piezoelectric resonator, the piezoelectric resonator comprising:

a piezoelectric body including a plurality of piezoelectric layers; and

N number of internal electrodes, wherein N equals 3, 4 or 5, disposed in the piezoelectric body and stacked on each other with the piezoelectric layers disposed therebetween; wherein

the piezoelectric body vibrates in an (N-1)th higher-order mode of a thickness extensional vibration mode and piezoelectric layers located between the internal electrodes are polarized in opposite direction alternately in the direction of thickness, and when the thickness of a piezoelectric layer between adjacent internal electrodes in the direction of thickness is denoted by D and the thicknesses of a first and second piezoelectric layer outside the outermost internal electrodes in the direction of thickness

Serial No. 09/648,523

January 20, 2003

Page 3 of 13

are denoted by D_1 and D_2 , the following relationships are satisfied: $0.60 \leq (D_1 + D_2)/2D \leq 0.90$ at $N = 3$, $0.65 \leq (D_1 + D_2)/2D \leq 0.90$ at $N = 4$, and $0.60 \leq (D_1 + D_2)/2D \leq 0.80$ at $N = 5$.

7. An energy-trap thickness extensional vibration mode piezoelectric resonator, comprising:

a piezoelectric body including a plurality of piezoelectric layers; and
 N number of internal electrodes, wherein N equals 3, 4 or 5, disposed in the piezoelectric body and stacked on each other with the piezoelectric layers disposed therebetween; wherein

the piezoelectric body vibrates in an $(N-1)$ th higher-order mode of a thickness extensional vibration mode and piezoelectric layers located between the internal electrodes are polarized in opposite direction alternately in the direction of thickness, and when the thickness of a piezoelectric layer between adjacent internal electrodes in the direction of thickness is denoted by D and the thicknesses of a first and second piezoelectric layer outside the outermost internal electrodes in the direction of thickness are denoted by D_1 and D_2 , the following relationships are satisfied: $0.10 \leq (D_1 + D_2)/2D \leq 0.90$ at $N = 3$, $0.10 \leq (D_1 + D_2)/2D \leq 0.90$ at $N = 4$, and $0.10 \leq (D_1 + D_2)/2D \leq 0.80$ at $N = 5$.